Appendix III-C
WASHINGTON STATE DEPARTMENT OF ECOLOGY LOW IMPACT DEVELOPMENT DESIGN AND FLOW MODELING GUIDANCE

The Washington State Department of Ecology (Ecology) encourages the use of the Western Washington Hydrology Model (WWHM) and other approved runoff models (currently approved alternative models are the King County Runoff Time Series and MGS Flood) for estimating surface runoff and sizing stormwater control and treatment facilities. This guidance suggests how to represent various LID techniques within those models so that their benefit in reducing surface runoff can be estimated. The lower runoff estimates should translate into smaller stormwater treatment and flow control facilities. In certain cases, use of various techniques can result in the elimination of those facilities.

The flow control credits presented in this chapter were developed by an LID credit committee comprised of stormwater managers from various local jurisdictions, WSU and Ecology.

This section identifies seven categories of LID techniques. For each category, the guidance lists basic design criteria that Ecology considers necessary in order to justify use of the suggested runoff "credit" or "runoff model representation." More detailed design guidance is available in the Low Impact Development Technical Guidance Manual for Puget Sound (LID Manual), published by the Puget Sound Water Quality Action Team and the Washington State University Cooperative Extension.

As Puget Sound gains more experience with and knowledge of LID techniques, the design criteria will evolve. Also, our ability to model their performance will change as our modeling techniques improve. Therefore, we anticipate this guidance will be updated periodically to reflect the new knowledge and modeling approaches. Meanwhile, we encourage all to use the guidance, and to give us feedback on its usefulness and accuracy. Comments can be sent to Ed O'Brien of the Washington State Department of Ecology at eobr461@ecy.wa.gov.

Note that the terminology for grass has changed in the WWHM. The term grass has been replaced with landscaped area.

7.1 Permeable Pavements

7.1.1 Credits

7.1.1.1 Porous Asphalt or Concrete

Description of Public Road or Public Parking lot | Model Surface as

1. Base material laid above surrounding grade:

a) Without underlying perforated drain pipes to collect stormwater	Grass over underlying soil type (till or outwash)
b) With underlying perforated drain pipes for stormwater collection:	
at or below bottom of base layer	Impervious surface
elevated within the base course	Impervious surface

2. Base material laid partially or completely below surrounding grade:

a) Without underlying perforated drain pipes	Option 1: Grass over underlying soil type Option 2: Impervious surface routed to an infiltration basin1
b) With underlying perforated drain pipes:	
at or below bottom of base layer	Impervious surface
elevated within the base course2	Model as impervious surface routed to an infiltration basin1

<u>Description of Private Facilities (driveways, parking lots, walks, patios)</u>

1. Base material below grade without underlying perforated drain pipes	50% grass on underlying soil; 50% impervious
2. Base material below grade with underlying perforated drain pipes	Impervious surface

7.1.1.2 Grid/lattice systems (non-concrete) and Paving Blocks

[1] See section 7.8 for detailed instructions concerning how to represent the base material below grade as an infiltration basin in the Western Washington Hydrology Model.
[2] If the perforated pipes function is to distribute runoff directly below the wearing surface, and the pipes are above the surrounding grade, follow the directions for 2a above.

Description of Public Road or Public Parking lot	Model Surface as
1. Base material laid above surrounding grade	
a) Without underlying perforated drain pipes	Grid/lattice systems: grass on underlying soil (till or outwash). Paving Blocks: 50% grass on underlying soil; 50% impervious.
b) With underlying perforated drain pipes	Impervious surface
2. Base material laid partially or completely below surrounding grade	
a) Without underlying perforated drain pipes	Option 1: Grid/lattice as grass on underlying soil. Paving blocks as 50% grass; 50% impervious. Option 2: Impervious surface routed to an infiltration basin.[1]
b) With underlying perforated drain pipes	
at or below bottom of base layer	Impervious surface
elevated within the base course2	Model as impervious surface routed to an infiltration basin.1

Description of Private Facilities (driveways, parking lots, walks, patios)	
Base material laid partially or completely below surrounding grade	
a) Without underlying perforated drain pipes	50% grass; 50% impervious
b) With underlying drain pipes	Impervious surface

7.1.2 Design Criteria for Permeable Pavements

Subgrade

- Compact the subgrade to the minimum necessary for structural stability. Use static dual wheel small mechanical rollers or plate vibration machines for compaction. Do not allow heavy compaction due to heavy equipment operation. The subgrade should not be subject to truck traffic.
- Use on soil types A through C.

Geotextile
- Use geotextile between the subgrade and base material/separation layer to keep soil out of base materials.
- The geotextile should pass water at a greater rate than the subgrade soils.

Separation or Bottom Filter Layer (recommended but optional)
- A layer of sand or crushed stone (0.5 inch or smaller) graded flat is recommended to promote infiltration across the surface, stabilize the base layer, protect underlying soil from compaction, and serve as a transition between the base course and the underlying geotextile material.

Base material
- Many design combinations are possible. The material must be free draining. For more detailed specifications for different types of permeable pavement, see section 6.2: Permeable Paving.
  - Driveways (recommendation):
    - ✓ > 4” layer of free-draining crushed rock, screened gravel, or washed sand.
    - ✓ < 5% fines (material passing thru #200 sieve) based on fraction passing #4 sieve.
  - Roads: The standard materials and quantities used for asphalt roads should be followed. For example:
    - ✓ Pierce Co. cites larger rock on bottom, smaller on top (e.g., 2” down to 5/8”); compacted; minimal fines; 8 inches total of asphaltic concrete and base material.
    - ✓ WSDOT lists coarse crushed stone aggregate (AASHTO Grading No. 57: 1.5 inch and lower); stabilized or unstabilized with modest compaction; meets fracture requirements.
    - ✓ FHWA suggests three layers between the porous pavement and geotextile. Typical layers would be:
      Filter course: 13 mm diameter gravel, 25 to 50 mm thick.
      Stone reservoir: 40-75 mm diameter stone.
      Filter course: 13 mm diameter gravel, 50 mm thick.

Wearing layer
- For all surface types, a minimum initial infiltration rate of 10 inches per hour is necessary. To improve the probability of long-term performance, significantly higher infiltration rates are desirable.
- *Porous Asphalt:* Products must have adequate void spaces through which water can infiltrate. A void space within the range of 12 – 20% is common.

- *Porous Concrete:* Products must have adequate void spaces through which water can infiltrate. A void space within the range of 15 – 21% is common.
- Grid/lattice systems filled with gravel, sand, or a soil of finer particles with or without grass: The fill material must be at least a minimum of 2 inches of sand, gravel, or soil. It should be underlain with 6 inches or more of sand or gravel to provide an adequate base. The fill material should be at or slightly below the top elevation of the grid/lattice structure. Modular-grid openings must be at least 40% of the total surface area of the modular grid pavement. Provisions for removal of oil and grease contaminated soils should be included in the maintenance plan.
- Paving blocks: 6 inches of sand or aggregate materials should fill spaces between blocks and must be free draining. Do not use sand for the leveling layer or filling spaces with EcoStone.
- The block system should provide a minimum of 12% free draining surface area.
- Provisions for removal of oil and grease contaminated soils should be included in the maintenance plan.

<u>Drainage conveyance</u>
Roads should still be designed with adequate drainage conveyance facilities as if the road surface was impermeable. Roads with base courses that extend below the surrounding grade should have a designed drainage flow path to safely move water away from the road prism and into the roadside drainage facilities. Use of perforated storm drains to collect and transport infiltrated water from under the road surface will result in less effective designs and less flow reduction credit.

<u>Acceptance test</u>
- Driveways can be tested by simply throwing a bucket of water on the surface. If anything other than a scant amount puddles or runs off the surface, additional testing is necessary prior to accepting the construction.
- Roads may be initially tested with the bucket test. In addition, test the initial infiltration with a 6-inch ring, sealed at the base to the road surface, or with a sprinkler infiltrometer. Wet the road surface continuously for 10 minutes. Begin test to determine compliance with 10 inches per hour minimum rate.

<u>Limitations</u>
- No run-on from pervious surfaces is preferred. If runoff comes from minor or incidental pervious areas, those areas must be fully stabilized.
- Slope impervious runoff away from the permeable pavement to the maximum extent practicable. Sheet flow from up-gradient impervious areas is not recommended, but permissible if porous surface flow path > impervious surface flow path. (Note: Impermeable surface that drains to a permeable pavement can also be modeled as noted above as long as the flow path restriction is met.
- Do not use at “high-use” sites, auto commercial services (gas stations, mini-marts, commercial fueling stations, auto body and auto repair shops, auto wash), commercial truck parking areas, areas with heavy industrial activity (as defined by USEPA regulations), or areas with high pesticide use.
- Soils must not be tracked onto the wear layer or the base course during construction.

- Slopes:
    - Asphalt: Works best on level slopes and up to 2%. Do not use on slopes $\geq$ 5%.
    - Concrete: Maximum recommended slope of 6%.
    - Interlocking pavers: Maximum recommended slope of 10%.
    - Grid/lattice systems: Maximum generally in 5-6% range.
- Do not use in areas subject to heavy, routine sanding for traction during snow and ice accumulation.
- Comply with local building codes for separation distances from buildings and wells. Inquire with the local jurisdiction concerning applicable setbacks.

<u>Maintenance</u>

- Inspect project upon completion to correct accumulation of fine material. Conduct periodic visual inspections to determine if surfaces are clogged with vegetation or fine soils. Clogged surfaces should be corrected immediately.
- Surfaces should be swept with a high-efficiency or vacuum sweeper twice per year; preferably, once in the autumn after leaf fall, and again in early spring. For porous asphalt and concrete surfaces, high pressure hosing should follow sweeping once per year.

7.2 Dispersion

7.2.1 Full Dispersion for the Entire Development Site (fulfills treatment and flow control requirements)

Developments that preserve 65% of a site (or a threshold discharge area of a site) in a forested or native condition, can disperse runoff from the developed portion of the site into the native vegetation area as long as the developed areas draining to the native vegetation do not have impervious areas that exceed 10% of the entire site. Runoff must be dispersed into the native area in accordance with the BMPs cited in BMP T5.30 of Volume V - Chapter 5. Additional impervious areas are allowed, but should not drain to the native vegetation area and are subject to the thresholds, treatment and flow control requirements of this stormwater manual.

7.2.2 Full Dispersion for All or Part of the Development Site

Developments that maintain ratios of:
$\geq$ 65% forested or native condition; and
$\leq$ 10% effective impervious surface of the area draining into the native vegetation area may disperse runoff into the native area in accordance with the BMPs cited in BMP T5.30 of Volume V - Chapter 5. Examples of such ratios are:

% Native Vegetation Preserved (min. allowed)	% Effective Impervious (max. allowed)	% Lawn/Landscape (max. allowed)
65	10	35
60	9	40
55	8.5	45

50	8	50*
45	7	55*
40	6	60*
35	5.5	65*

* Where these lawn/landscape areas are established on till soils, and exceed 50% of the total site, they should be developed using guidelines in BMP T5.13 of Volume V – Chapter 5, or a locally approved alternative soil quality and depth specification.

Within the context of this dispersion option, the only impervious surfaces that are ineffective are those that are routed into an appropriately sized dry well or into an infiltration basin that meets the flow control standard and does not overflow into the forested or native vegetation area.

Note: For options in 7.2.1 and 7.2.2, native vegetation areas must be protected from future development. Protection must be provided through legal documents on record with the local government. Examples of adequate documentation include: a conservation easement, conservation parcel, deed restriction.

7.2.3 Partial Dispersion on residential lots and commercial buildings

If roof runoff is dispersed on single-family lots greater than 22,000 square feet, according to the design criteria and guidelines in BMP T5.10 of Volume V - Chapter 5, and the vegetative flow path is 50 feet or larger through undisturbed native landscape or lawn/landscape area that meets the guidelines in BMP T5.13, the roof area may be modeled as landscaped area. This is done by clicking on the "Credits" button in the WWHM and entering the percent of roof area that is being dispersed.

The vegetated flow path is measured from the downspout or dispersion system discharge point to the downstream property line, stream, wetland, or other impervious surface.

Where BMP T5.11 (concentrated flow dispersion) or BMP T5.12 (sheet flow dispersion) of Volume V – Chapter 5 is used to disperse runoff into a native vegetation area or an area that meets the guidelines in BMP T5.13 of Volume V – Chapter 5, the impervious area may be modeled as landscaped area. This can be done by entering the impervious area as landscaped area rather than entering it as impervious area.

7.2.4 Road Projects

1) <u>Uncollected or natural dispersion into adjacent vegetated areas</u> (i.e., sheet flow into the dispersion area).

Full dispersion credit (i.e. no other treatment or flow control required) for sites that meet the following criteria:

a) *Outwash soils* (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that have an initial saturated infiltration rate of 4 inches per hour or greater. The infiltration rate must be based on one of the following: (1) A D_{10} size (10% passing the size listed) greater than 0.06 mm (based on the estimated infiltration rate indicated by the upper-bound line in Figure 3.26a of Volume III – Chapter 3 for the finest soil within a three foot depth; (2) field results using procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V.

- 20 feet of impervious flow path needs 10 feet of dispersion area width.
- Each additional foot of impervious flow path needs 0.25 feet of dispersion area width.

b) *Other soils:* (Types C and D and some Type B not meeting the criterion in 1a above)

- Dispersion area must have 6.5 feet of width for every 1 foot width of impervious area draining to it. A minimum distance of 100 feet is necessary.

c) *Criteria applicable to all soil types:*

- Depth to the average annual maximum groundwater elevation should be at least 3 feet.
- Impervious surface flow path must be $\leq$ 75 ft. Pervious flow path must be $\leq$ 150 ft. Pervious flow paths are up-gradient road side slopes that run onto the road and down-gradient road side slopes that precede the dispersion area.
- Lateral slope of impervious drainage area should be $\leq$ 8%. Road side slopes must be $\leq$ 25%. Road side slopes do not count as part of the dispersion area unless native vegetation is re-established and slopes are less than 15%. Road shoulders that are paved or graveled to withstand occasional vehicle loading count as impervious surface.
- Longitudinal slope of road should be $\leq$ 5%.
- Length of dispersion area should be equivalent to length of road.
- Average longitudinal (parallel to road) slope of dispersion area should be $\leq$ 15%.
- Average lateral slope of dispersion area should be $\leq$ 15%.

2) <u>Channelized (collected and re-dispersed) stormwater into areas with (a) native vegetation or (b) cleared land in areas outside of Urban Growth Areas that do not have a natural or man-made drainage system.</u>

Full dispersion credit (i.e., no other treatment or flow control required) is given to projects that meet the following criteria:

a) *Outwash soils* (Type A – sands and sandy gravels, possibly some Type B – loamy sands) that have an initial saturated infiltration rate of 4 inches per hour or greater. The infiltration rate must be based on one of the following: (1) A D_{10} size (10% passing the size listed) greater than 0.06 mm (based on the estimated infiltration rate indicated by the upper-bound line in Figure 3.26a of Volume III – Chapter 3 for the finest soil within a three foot depth; 2 field results using procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V.

- Dispersion area should be at least ½ of the impervious drainage area.

b) *Other soils:* (Types C and D and some Type B not meeting the criterion in 2a above)

- Dispersion area must have 6.5 feet of width for every 1 foot width of impervious area draining to it. A minimum distance of 100 feet is necessary.

c) *Other criteria applicable to all soil types*:

- Depth to the average annual maximum groundwater elevation should be at least three feet.
- Channelized flow must be redispersed to produce longest possible flow path.
- Flows must be evenly dispersed across the dispersion area.
- Flows must be dispersed using rock pads and dispersion techniques as specified in BMP T5.30, of Volume V – Chapter 5.
- Approved energy dissipation techniques may be used.
- Limited to onsite (associated with the road) flows.
- Length of dispersion area should be equivalent to length of the road.
- Average longitudinal and lateral slopes of the dispersion area should be $\leq$ 8%.

3) <u>Engineered dispersion of stormwater runoff into an area with engineered soils</u>

Full dispersion credit (i.e., no other treatment or flow control required) is given to projects that meet the following criteria:

- Stormwater can be dispersed via sheet flow or via collection and re-dispersion in accordance with the techniques specified in BMP T5.30 in Volume V – Chapter 5.
- Depth to the average annual maximum groundwater elevation should be at least three feet.
- Type C and D soils must be compost-amended following guidelines in BMP T5.13 of Volume V – Chapter 5. The guidance document *Guidelines and Resources for Implementing Soil Depth & Quality BMP T5.13 in WDOE Western Washington Stormwater Manual*, 2003 can be used, or an approved equivalent soil quality and depth specification approved by the Department of Ecology.
  - Dispersion area must meet the 6.5 to 1 ratio for full dispersion credit.
- Type A and B soils that meet the 4 inches per hour initial saturated infiltration rate minimum (See Section 2.D.1. above) must be compost amended in accordance with guidelines in BMP T5.13 of Volume V – Chapter 5. Compost may be incorporated into the soil in accordance with the guidance document cited above, or can be placed on top the native soil.
  - 20 feet of impervious flow path needs 10 feet of dispersion area width.
  - Each additional foot of impervious flow path needs 0.25 feet of dispersion area width.
- Average longitudinal (parallel to road) slope of dispersion area should be $\leq$ 15%.
- Average lateral slope of dispersion area should be $\leq$ 15%.

- The dispersion area should be planted with native trees and shrubs.

4) <u>Other Characteristics for Dispersal areas</u>

- Dispersal areas must be outside of the urban growth area; or if inside the urban growth area, in legally protected areas (easements, conservation tracts, public parks).
- If outside urban growth areas, legal agreements should be reached with property owners of dispersal areas subject to stormwater that has been collected and is being re-dispersed.
- An agreement with the property owner is advised for uncollected, natural dispersion via sheet flow that represents a continuation of past practice. If not a continuation of past practice, an agreement should be reached with the property owner.

7.3 Vegetated Roofs

7.3.1 Option 1 Design Criteria

- 3 inches to 8 inches of soil/growing media

Runoff Model Representation

- till landscaped area

7.3.2 Option 2 Design Criteria

- $\geq$ 8 inches of soil/media

Runoff Model Representation

- till pasture

7.3.3 Other Necessary Design Criteria

- Soil or growth media that has a high field capacity, and a saturated hydraulic conductivity that is $\geq$ 1 inch/hour (i.e., equivalent to a sandy loam or soil with a higher hydraulic conductivity).
- Drainage layer that allows free drainage under the soil/media.
- Vegetative cover that is both drought and wet tolerant.
- Waterproof membrane between the drain layer and the structural roof support.
- Maximum slope of 20%.

7.4 Rainwater Harvesting

7.4.1 Design Criteria

- 100% reuse of the annual average runoff volume (use continuous runoff model to get annual average for drainage area).
- System designs involving interior uses must have a monthly water balance that demonstrates adequate capacity for each month and reuse of all stored water annually.

Runoff Model Representation:

- Do not enter drainage area into the runoff model.

7.4.2 Other Criteria

- Restrict use to 4 homes/acre housing and lower densities when the captured water is solely for outdoor use.

7.5 Reverse Slope Sidewalks

Reverse slope sidewalks are sloped to drain away from the road and onto adjacent vegetated areas.

7.5.1 Design Criteria:

- $\geq$ 10 feet of vegetated surface downslope that is not directly connected into the storm drainage system.
- Vegetated area receiving flow from sidewalk must be native soil or meet guidelines in BMP T5.13 of Volume V – Chapter 5.

7.5.2 Runoff Model Representation:

- Enter sidewalk area as landscaped area.

7.6 Minimal Excavation Foundations

Low impact foundations are defined as those techniques that do not disturb, or minimally disturb the natural soil profile within the footprint of the structure. This preserves most of the hydrologic properties of the native soil. Pin foundations are an example of a minimal excavation foundation.

7.6.1 Runoff Model Representation

- Where residential roof runoff is dispersed on the up gradient side of a structure in accordance with the design criteria and guidelines in BMP T5.10 of Volume V – Chapter 5, the tributary roof area may be modeled as pasture on the native soil.
- Where "step forming" is used on a slope, the square footage of roof that can be modeled as pasture must be reduced to account for lost soils. In "step forming," the building area is terraced in cuts of limited depth. This results in a series of level plateaus on which to erect the form boards. The following equation (suggested by Rick Gagliano of Pin Foundations, Inc.) can be used to reduce the roof area that can be modeled as pasture.

$$A_1 - \frac{dC(.5)}{dP} X A_1 = A_2$$

A_1 = roof area draining to up gradient side of structure
dC = depth of cuts into the soil profile

dP = permeable depth of soil (The A horizon plus an additional few inches of the B horizon where roots permeate into ample pore space of soil).

A_2 = roof area that can be modeled as pasture on the native soil

- If roof runoff is dispersed down gradient of the structure in accordance with the design criteria and guidelines in BMP T5.10 of Volume V – Chapter 5, AND there is at least 50 feet of vegetated flow path through native material or lawn/landscape area that meets the guidelines in BMP T5.13 of Volume V – Chapter 5, the tributary roof areas may be modeled as landscaped area.

7.6.2 Limitations

- To minimize soil compaction, heavy equipment cannot be used within or immediately surrounding the building. Terracing of the foundation area may be accomplished by tracked, blading equipment not exceeding 650 psf.

7.7 Bioretention areas (rain gardens)

The design criteria provided below outlines basic guidance on bioretention design specifications, procedures for determining infiltration rates, and flow control guidance. For details on design specifications see section 6.1: Bioretention Areas of the Low Impact Development Technical Guidance Manual for Puget Sound (LID Manual).

7.7.1 Design Criteria

Soils

- The soils surrounding bioretention facilities are a principle design element for determining infiltration capacity, sizing and rain garden type. The planting soil mix placed in the cell or swale is a highly permeable soil mixed thoroughly with compost amendment, and a surface mulch layer.
- Soil depth should be a minimum of 18 inches to provide acceptable minimum pollutant attenuation and good growing conditions for selected plants.
- The texture for the soil component of the bioretention soil mix should be a loamy sand (USDA Soil Textural Classification). Clay content for the final soil mix should be less than 5 percent. The final soil mix (including compost and soil) should have a minimum short-term hydraulic conductivity of 1.0 inches/hour per ASTM Designation D 2434 (Standard Test Method for Permeability of Granular Soils) at 80 percent compaction per ASTM Designation D 1557.
- The final soil mixture should have a minimum organic content of approximately 10 percent by dry weight.
- The pH for the soil mix should be between 5.5 and 7.0.

Mulch layer

- Bioretention areas can be designed with or without a mulch layer.

Compost

- Material must be in compliance with WAC chapter 173-350 section 220 and meet Type 2,3 or 4 feedstock.
- pH between 5.5 and 7.0.
- Carbon nitrogen ratio between 20:1 and 35:1 (35:1 CN ratio recommended for native plants)
- Organic matter content should be between 40% and 50%.

Installation

- Minimize compaction of the base and sidewalls of the bioretention area. Excavation should not be allowed during wet or saturated conditions. Excavation should be performed by machinery operating adjacent to the bioretention facility and no heavy equipment with narrow tracks, narrow tires or large lugged, high pressure tires should be allowed on the bottom of the bioretention facility.
- On-site soil mixing or placement should not be performed if soil is saturated. The bioretention soil mixture should be placed and graded by excavators and/or backhoes operating adjacent to the bioretention facility.

Plant materials

- Plants should be tolerant of ponding fluctuations and saturated soil conditions for the length of time anticipated by the facility design, and drought during the summer months.
- In general, the predominant plant material utilized in bioretention areas are facultative species adapted to stresses associated with wet and dry conditions.

Maximum ponding depth

- A maximum ponding depth of 12 inches is recommended.
- A maximum surface pool drawdown time of 24 hours is recommended.
- Ponding depth and system drawdown should be specified so that soils dry out periodically in order to:
  - Restore hydraulic capacity to receive flows from subsequent storms.
  - Maintain infiltration rates.
  - Maintain adequate soil oxygen levels for healthy soil biota and vegetation.
  - Provide proper soil conditions for biodegradation and retention of pollutants.

7.7.2 Limitations

- A minimum of 3 feet of clearance is necessary between the lowest elevation of the bioretention soil, or any underlying gravel layer, and the seasonal high groundwater elevation or other impermeable layer if the area tributary to the rain garden meets or exceeds any of the following limitations:
  - 5,000 square feet of pollution-generating impervious surface; or
  - 10,000 square feet of impervious area; or
  - ¾ acres of lawn and landscape.
- If the tributary area to an individual rain garden does not exceed the areal limitations above, a minimum of 1 foot of clearance is adequate between the lowest elevation of

the bioretention soil (or any underlying gravel layer) and the seasonal high groundwater elevation or other impermeable layer.

7.7.3 Runoff Model Representation

<u>Pothole design (bioretention cells)</u>
The rain garden is represented as a pond with a steady-state infiltration rate. Proper infiltration rate selection is described below. The pond volume is a combination of the above ground volume available for water storage and the volume available for storage within the imported soil. The latter volume is determined by multiplying the volume occupied by the imported soil by the soil's percent porosity. Use 40 percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual. That volume is presumed to be added directly below the surface soil profile of the rain garden. The theoretical pond dimensions are represented in the Pond Information/Design screen. The Effective Depth is the distance from the bottom of the theoretical pond to the height of the overflow. This depth is less than the actual depth because of the volume occupied by the soil. Approximate side slopes can be individually entered. On the Pond Information/Design screen, there is a button, which asks, "Use Wetted Surface Area?" Pushing that button is an affirmative response. Do not push the button if the rain garden has sidewalls steeper than 2 horizontal to 1 vertical.

Rain gardens with underlying perforated drain pipes that discharge to the surface can also be modeled as ponds with steady-state infiltration rates. However, the only volume available for storage (and modeled as storage as explained herein) is the void space within the imported material (usually sand or gravel) below the invert of the drain pipe.

<u>Linear Design: (bioretention swale or slopes)</u>
Swales
Where a swale design has a roadside slope and a back slope between which water can pond due to an elevated, and an overflow/drainage pipe at the lower end of the swale, the swale may be modeled as a pond with a steady state infiltration rate. This method does not apply to swales that are underlain by a drainage pipe.

If the long-term infiltration rate through the imported bioretention soil is lower than the infiltration rate of the underlying soil, the surface dimensions and slopes of the swale should be entered into the WWHM as the pond dimensions and slopes. The effective depth is the distance from the soil surface at the bottom of the swale to the invert of the overflow/drainage pipe. If the infiltration rate through the underlying soil is lower than the estimated long-term infiltration rate through the imported bioretention soil, the pond dimensions entered into the WWHM should be adjusted to account for the storage volume in the void space of the bioretention soil. Use 40 percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual. For instance, if the soil is 40% voids, and the depth of the imported soils is 2 feet throughout the swale, the depth of the pond is increased by 0.8 feet. If the depth of imported soils varies within the side slopes of the swale, the theoretical side slopes of the pond can be adjusted.

This procedure to estimate storage space should only be used on bioretention swales with a 1% slope or less. Swales with higher slopes should more accurately compute the storage volume in the swale below the drainage pipe invert.

Slopes
Where a bioretention design involves only a sloped surface such as the slope below the shoulder of an elevated road, the design can also be modeled as a pond with a steady state infiltration rate. This procedure only applies in instances where the infiltration rate through the underlying soil is less than the estimated long-term infiltration rate of the bioretention imported soil. In this case, the length of the bioretention slope should correspond to the maximum wetted cross-sectional area of the theoretical pond. The effective depth of the theoretical pond is the void depth of the bioretention soil as estimated by multiplying the measured porosity times the depth of the bioretention soils. Use 40 percent porosity for bioretention planting mix soils recommended in section 6.1.2.3: Bioretention components of the LID Manual.

7.7.4 Infiltration Rate Determinations

The assumed infiltration rate for the pond must be the lower of the estimated long-term rate of the imported soil or the initial (a.k.a. short-term or measured) infiltration rate of the underlying soil profile. Using one of the procedures explained below, the initial infiltration rates of the two soils must be determined. Then after applying an appropriate correction factor to the imported soil of the rain garden, the designer can compare and determine the lower of the long-term infiltration rate of the imported soil, and the initial infiltration rate of the underlying native soil. The underlying native soil does not need a correction factor because the overlying imported soil protects it. Below are explanations for how to determine infiltration rates for the imported and underlying soils, and how to use them with the WWHM.

7.7.4.1 Imported Soil for the rain garden

1. Method for imported soil in a rain garden with a tributary area of or exceeding any of the following limitations: 5,000 square feet of pollution-generating impervious surface; or 10,000 square feet of impervious surface; or ¾ acres of lawn and landscape:
   - Use ASTM D 2434 Standard Test Method for Permeability of granular Soils (Constant Head) with a compaction rate of 80% using ASTM D1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort.
   - Use **4** as the infiltration reduction correction factor.
   - Compare this rate to the infiltration rate of the underlying soil (as determined using one of the methods below). If the long-term infiltration rate of the imported soil is lower, enter that infiltration rate and the correction factor into the corresponding boxes on the pond information/design screen of the WWHM.

2. Method for imported soil in a rain garden with a tributary area less than 5,000 square feet of pollution-generating impervious surface; and less than 10,000 square feet of impervious surface; and less than ¾ acres of lawn and landscape:

- Use ASTM D 2434 Standard Test Method for Permeability of granular Soils (Constant Head) with a compaction rate of 80% using ASTM D1557 Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort.
- Use **2** as the infiltration reduction correction factor.
- Compare this rate to the infiltration rate of the underlying soil (as determined using one of the methods below). If the long-term infiltration rate of the imported soil is lower, enter that infiltration rate and the correction factor into the corresponding boxes on the pond information/design screen of the WWHM.

7.7.4.2 Underlying Soil:

- Method 1: Use Table 3.7of the 2004 SMMWW to determine the short-term infiltration rate of the underlying soil. Soils not listed in the table cannot use this approach. Compare this short-term rate to the long-term rate determined above for the bioretention imported soil. If the short-term rate for the underlying soil is lower, enter it into the measured infiltration rate box on the pond information/design screen in the WWHM. Enter 1 as the infiltration reduction factor.
- Method 2: Determine the D_{10} size of the underlying soil. Use the "upperbound line" in Figure 3-26a of Volume III – Chapter 3 to determine the corresponding infiltration rate. If this infiltration rate is lower than the long-term infiltration rate determined for the imported bioretention soil, enter the rate for the underlying soil into the measured infiltration rate box on the pond/information design screen. Enter 1 as the infiltration reduction factor.
- Method 3: Measure the in situ infiltration rate of the underlying soil using procedures (Pilot Infiltration Test) identified in Appendix V-B of Volume V. If this rate is lower than the long-term infiltration rate determined for the imported bioretention soil, enter the underlying soil infiltration rate into the corresponding box on the pond information/design screen of the WWHM. Enter 1 as the infiltration reduction factor.

7.7.5 WWHM Routing and Runoff File Evaluation

In WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage be exceeded. So in the Riser/Weir screen, for the Riser head enter a value slightly smaller than the effective depth of the pond (say 0.1 ft below the Effective Depth); and for the Riser diameter enter a large number (say 10,000 inches) to ensure that there is ample capacity for overflows.

Within the model, route the runoff into the pond by grabbing the pond icon and placing it below the tributary "basin" area. Be sure to include the surface area of the bioretention area in the tributary "basin" area. Run the model to produce the effluent runoff file from the theoretical pond. For projects subject to the flow control standard, compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. A conveyance system should be designed to route all overflows from the bioretention areas to centralized treatment facilities, and to flow control facilities if flow control applies to the project

7.7.6 Modeling of Multiple Rain Gardens

Where multiple rain gardens are scattered throughout a development, it may be possible to represent those as one rain garden (a "pond" in the WWHM) serving the cumulative area tributary to those rain gardens. For this to be a reasonable representation, the design of each rain garden should be similar (e.g., same depth of soil, same depth of surface ponded water, roughly the same ratio of impervious area to rain garden volume).

7.7.7 Other Rain Garden Designs

Guidance for modeling other bioretention designs is not yet available. However, where compost-amended soils are used along roadsides the guidance in section 7.2: Dispersion can be applied.

7.8 WWHM Instructions for Estimating Runoff Losses in Road Base Material Volumes that are Below Surrounding Grade

Pre-requisite

Before using this guidance to estimate infiltration losses, the designer should have sufficient information to know whether adequate depth to a seasonal high groundwater table, or other infiltration barrier (such as bedrock) is available. The minimum depth necessary is 3 feet as measured from the bottom of the base materials.

7.8.1 Instructions for Roads on Zero to 2% Grade

For road projects whose base materials extend below the surrounding grade, a portion of the below grade volume of base materials may be modeled in the WWHM as a pond with a set infiltration rate.

First, place a "basin" icon in the "Schematic" grid on the left side of the "Scenario Editor" screen. Left clicking on the basin icon will create a "basin information" screen on the right in which you enter the appropriate pre-developed and post-developed descriptions of your project site (or threshold discharge area of the project site). By placing a pond icon below the basin icon in the Schematic grid, we are routing the runoff from the road and any other tributary area into the below grade volume that is represented by the pond.

The dimensions of the infiltration basin/pond to be entered in the Pond Information/Design screen are: the length of the base materials that are below grade (parallel to the road); the width of the below grade material volume; and the Effective Depth. Note that the storage/void volume of the below grade base has to be estimated to account for the percent porosity of the gravel. This can be done by multiplying the below grade depth of base materials by the fractional porosity (e.g., a project with a gravel base of 32% porosity would multiply the below grade base material depth by 0.32). This is the Effective Depth. If the below grade base course has perforated drainage pipes elevated above the bottom of the base course, but below the elevation of the surrounding ground surface, the Effective Depth is the distance from the invert of the lowest pipe to the bottom of the base course multiplied by the fractional porosity.

Also in WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. So in the Riser/Weir screen, for the Riser head enter a value slightly smaller than the effective depth of the base materials (say 0.1 ft below the Effective Depth); and for the Riser diameter enter a large value (say 10,000 inches) to ensure that there is ample capacity should overflows from the trench occur.

On the Pond Information/Design screen, there is a button that asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. Do not push the button.

Using the procedures explained in Volume III - Chapter 3 and Appendix V-B of the 2004 SMMWW, estimate the long-term infiltration rate of the native soils beneath the base materials. If using Method 1 from Chapter 3 of Volume III, enter the appropriate “short-term infiltration rate” from Table 3.7 into the “measured infiltration rate” box on the “Pond Information Design” screen of WWHM. Enter the correction factor from that table as the “Infiltration Reduction Factor.” If using Method 2, enter the appropriate long-term infiltration rate from Table 3.8 into the “measured infiltration rate” box. Enter “1” as the correction factor. Note that Table 3.8 is restricted to the soil types in the table. For soils with a D_{10} size smaller than .05 mm, use the “lowerbound” values from Figure 3-26a in Volume III – Chapter 3. If using Method 3, enter the measured in-situ infiltration rate as the “Measured Infiltration Rate” in the Pond Information/Design Screen. Also enter the appropriate cumulative correction factor determined from Table 3.9 as the “Infiltration Reduction Factor.” Wherever practicable, Ecology recommends using Method 3, in-situ infiltration measurements (Pilot Infiltration Test) in accordance with Appendix V-B of Volume V – Chapter 5.

Run the model to produce the overflow runoff file from the base materials infiltration basin. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.

7.8.2 Instructions for Roads on Grades above 2%

Road base material volumes that are below the surrounding grade and that are on a slope, can be modeled as a pond with an infiltration rate and a nominal depth. Represent the below grade volume as a pond. Grab the pond icon and place it below the “basin” icon so that the computer model routes all of the runoff into the infiltration basin/pond

The dimensions of the infiltration basin/pond to be entered in the Pond Information/Design screen are: the length (parallel to and beneath the road) of the base materials that are below grade; the width of the below grade base materials; and an Effective Depth of 1 inch. In WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. So in the Riser/Weir screen, enter 0.04 ft (½ inch) for the Riser head and a large Riser diameter (say 1000 inches) to ensure that there is no head build up.

Note: If a drainage pipe is embedded and elevated in the below grade base materials, the pipe should only have perforations on the lower half (below the spring line) or near the invert. Pipe volume and trench volume above the pipe invert cannot be assumed as available storage space.

Estimate the infiltration rate of the native soils beneath the base materials. See the previous section (Instructions for Roads on Zero to 2% Grade) for estimating options and for how to enter infiltration rates and infiltration reduction factors into the “Pond Information/ Design” Screen of WWHM. Enter the appropriate information for the theoretical pond of ½-inch maximum depth.

On the Pond Information/Design screen, there is a button that asks, “Use Wetted Surface Area?” Pushing that button is an affirmative response. Do not push the button.

Run the model to produce the effluent runoff file from the base materials. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.

7.8.3 Instructions for Roads on a Slope with Internal Dams within the Base Materials that are Below Grade

In this option, a series of infiltration basins is created by placing relatively impermeable barriers across the below grade base materials at intervals. The barriers inhibit the free flow of water down the grade of the base materials. The barriers must not extend to the elevation of the surrounding ground. Provide a space sufficient to pass water from upgradient to lower gradient basins without causing flows to surface out the sides of the base materials that are above grade.

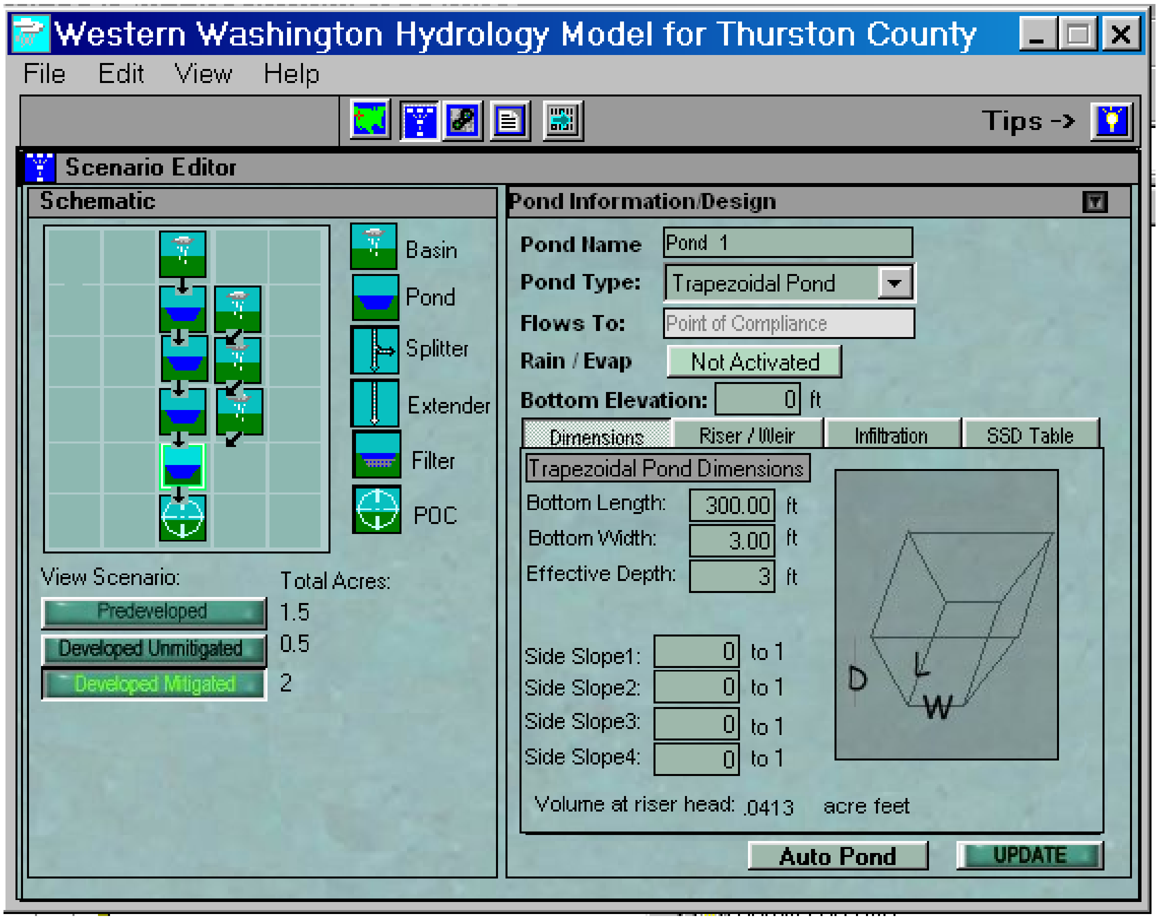
Each stretch of trench (cell) that is separated by barriers can be modeled as an infiltration basin. This is done by placing pond icons in series in the WWHM. For each cell, determine the average depth of water within the cell (Average Cell Depth) at which the barrier at the lower end will be overtopped.

Specify the dimensions of each cell of the below-grade base materials in WWHM on the screen, which asks for pond dimensions. The dimensions of the infiltration cell to be entered in the Pond Information/Design screen are: the length of the cell (parallel to the road); the width; and the Effective Depth (In this case, it is OK to use the total depth of the base materials that are below grade).

Also in WWHM2, all infiltrating facilities must have an overflow riser to model overflows that occur should the available storage get exceeded. For each trench cell, the available storage is the void space within the Average Cell Depth. So, the storage/void volume of the trench cell has to be estimated to account for the percent porosity of the base materials. For instance, if the base materials have a porosity of 32%, the void volume can be represented by reducing the Average Cell Depth by 68% (1-32%). This depth is entered in the Riser/Weir screen as the Riser head. The gross adjustment works because WWHM2 (as March 2004) does not adjust infiltration rate as a function of water head. If the model is amended such that the infiltration rate becomes a function of water head, this gross adjustment will introduce error and therefore other adjustments should be made.) For the ***Riser diameter*** in the Riser/Weir screen,, enter a large number (say 10,000 inches) to ensure that there is ample capacity should overflows from the below-grade trench occur.

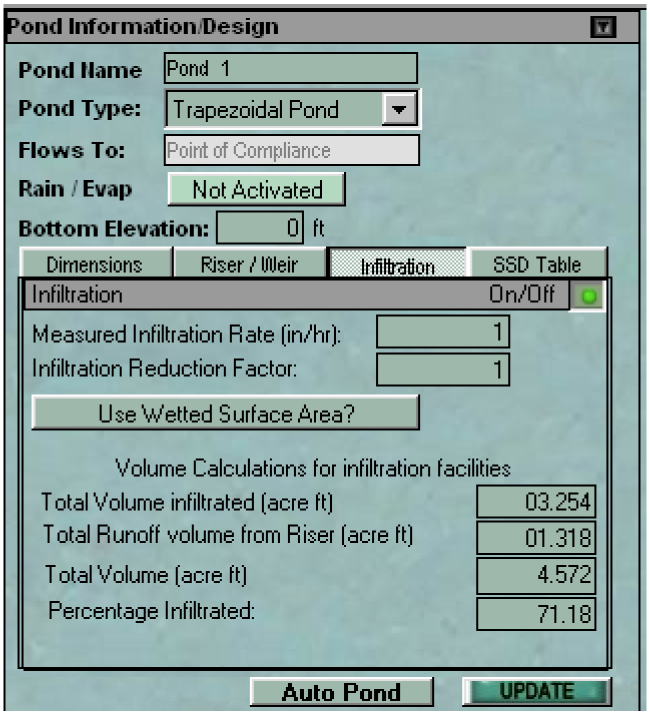
Each cell should have its own tributary drainage area that includes the road above it, any project site pervious areas whose runoff drains onto and through the road, and any offsite areas. Each drainage area is represented with a “basin” icon.

Up to four pond icons can be placed in a series to represent the below grade trench of base materials. The computer graphic representation of this appears as follows:



It is possible to represent a series of cells as one infiltration basin (using a single pond icon) if the cells all have similar length and width dimensions, slope, and Average Cell Depth. A single "basin" icon is also used to represent all of the drainage area into the series of cells.

On the Pond Information/Design screen (see screen below), there is a button, which asks, "Use Wetted Surface Area?" Pushing that button is an affirmative response. Do not push the button if the below-grade base material trench has sidewalls steeper than 2 horizontal to 1 vertical.



Using the procedures explained above for roads on zero grade, estimate the infiltration rate of the native soils beneath the trench. Also as explained above, enter the appropriate values into the “Measured Infiltration Rate” and “Infiltration Reduction Factor” boxes of the “Pond Information/Design” screen.

Run the model to produce the effluent runoff file from the below grade trench of base materials. Compare the flow duration graph of that runoff file to the target pre-developed runoff file for compliance with the flow duration standard. If the standard is not achieved a downstream retention or detention facility must be sized (using the WWHM standard procedures) and located in the field. The road base materials should be designed to direct any water that does not infiltrate into a conveyance system that leads to the retention or detention facility.